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Effect of Soil Applications of Insecticides on the Growth and Yield of Vegetable Crops[1]

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INTRODUCTION

The effect of residues from soil applications of insecticides on the growth of plants has long been a matter of concern to entomologists as well as the insecticide industry. This problem has been intensified during recent years, particularly in southern California, by the widespread use of the new organic insecticides for the control of soil-inhabiting insects such as wireworms and other root feeders. In 1949 an experiment was begun in Ventura County to determine the effect of repeated soil applications of aldrin, chlordane, toxaphene, and ethylene dibromide on vegetable crops grown in treated plots. The results obtained during the first 3 years of the experiment are presented in this circular.

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[3] The authors acknowledge the assistance of Roy Hudson in 1949, C. O. Gaston and A. Sarinana in 1950, and W. Larramedy in 1951. The lima bean growers Joseph and John Laubacher also assisted and furnished tractors and equipment for incorporating the insecticides with the soil. The Vujovich Bros. provided irrigation pipe. The Coastal Chemical Co. and the McCrae Chemical Co. applied the soil fumigants. The following companies furnished insecticides: Eston Chemicals, Inc., Hercules Powder Co., Velsicol Corp., and the Julius Hyman Co. The writers are also indebted to H. K. Burr and staff of the Western Regional Laboratory of the Bureau of Agricultural and Industrial Chemistry for appraising the flavor of several of the crops. The California Lima Bean Growers Assoc. furnished a portable engine-driven lima bean thresher.

REVIEW OF LITERATURE

Allen and coworkers *(1)*[4] and Foster *(3)* have published extensive reviews of the literature on the effect of soil applications of insecticides on the growth and yield of crops. Recently Simkover and Shenefelt *(5)* reported that root nodulation on black locust seedlings was not affected by soil applications of 10 pounds of chlordane and sufficient technical BHC to give 1 pound of the gamma isomer per acre. Tiedjens *(6)* discussed the effect of insecticide-fertilizer mixtures on soil insects, as well as their phytotoxic and off-flavor effects on crops, and stated that workers in Kansas had found that aldrin in dosages as high as 100 pounds per acre caused no objectionable flavor. Preliminary experiments on the toxicity of cumulative residues in the soil to plant and animal life have been reported by Gould and Hamstead *(4)*.

GENERAL PROCEDURE

The studies in California were conducted on the farm of J. Laubacher, about 1 mile west of Oxnard. The soil consisted of Yolo fine sandy loam, which had been planted to lima beans for many years and to alfalfa for 3 years prior to these experiments. To prevent the test insecticides from affecting plant growth and yield by controlling wireworms and nematodes, these pests were controlled on the entire site by fumigation with ethylene dibromide on March 8 following thorough cultivation of the soil. No insecticides other than fumigants had ever been used either on the crops or in the soil.

Experimental Method

Each insecticide was tested in six randomized blocks containing plots 21 by 160 feet, or approximately 1/13 acre. To expedite planting and harvesting, roadways were established the entire length of the site on both sides and between blocks 2 and 3 and blocks 4 and 5. The plots adjoined each other, but no crops were planted within 4 feet of the borders (fig. 1). The entire site was prepared for planting on March 8, 1949, prior to fumigation, and on March 14 it was furrowed and irrigated.

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[4] Italic figures in parentheses refer to Literature cited, page 19.

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The test insecticides were applied on April 11 and October 26, 1949, and on November 15, 1950, before the crops were planted. Aldrin was applied at 4 pounds, chlordane at 20 pounds, and toxaphene at 20 pounds per acre. These insecticides were applied as sprays made from wettable powder formulations. Applications were made with a power sprayer equipped with a 10½-foot boom with nozzles spaced 12 inches apart. Immediately after application the soil was thoroughly disked 8 inches deep in two directions, to mix the insecticides with the soil (fig. 2). Ethylene dibromide was injected into the soil 6 to 7 inches deep, at 12-inch spacings, with a soil-fumigant applicator, the dosage being equivalent to 54 pounds per acre. A heavy steel bar attached to the rear of the applicator sealed any openings made by the injector blades.

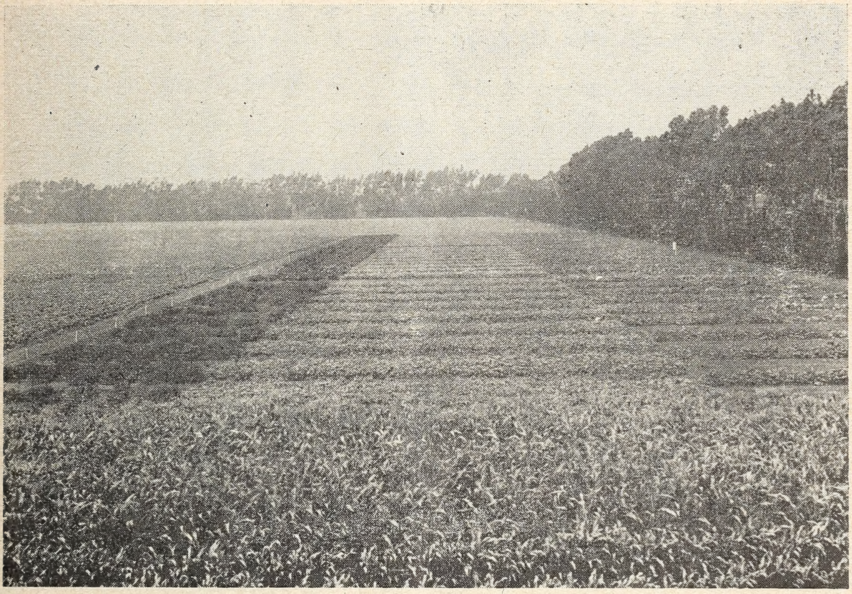

FIGURE 1.—Three-acre site near Oxnard, Calif., used for studying the effect of soil applications of insecticides on various crops.

To prevent relocation of the insecticides at lower soil depths, the soil was never ploughed. The formation of a plow sole was prevented by subsoiling 20 inches deep, at 20-inch spacings, prior to winter rains, on December 5, 1949, and on December 15, 1950. A deficiency in rainfall during the years in which these experiments were conducted (table 1) made it necessary to irrigate the plots before planting, usually in March. This is a common practice among growers during years of light rainfall. The effect of the treatments on the plant stand was determined by counting the plants in each row before harvesting.

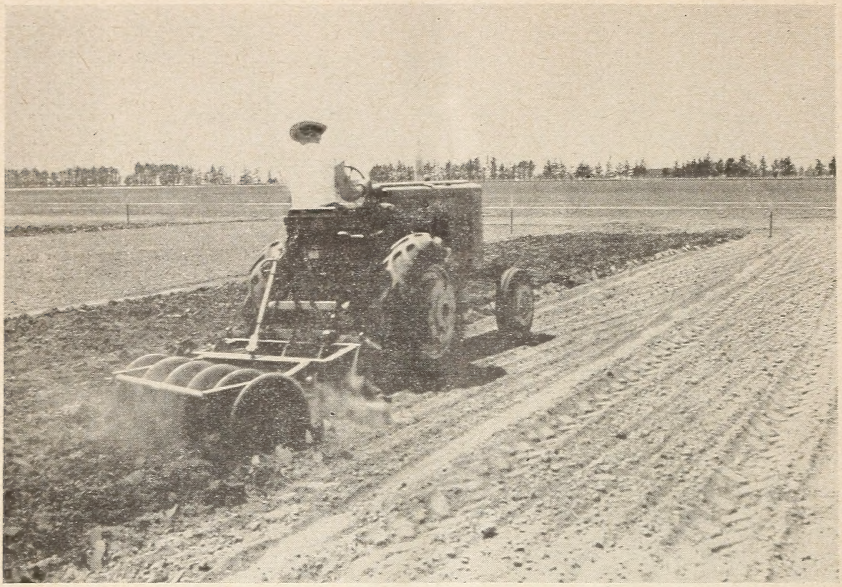

FIGURE 2.—Disking to incorporate the insecticide with the soil.

CULTURAL PRACTICES

The soil was prepared for planting in the usual manner. In 1950 an ammonium nitrate fertilizer (32.5 percent nitrogen) was applied over the entire site at the rate of 260 pounds per acre and disked in. In 1951 an ammonium phosphate fertilizer (16 percent nitrogen, 20 percent phosphorus) was applied at the same rate. No fertilizer was applied before the 1949 crop was planted.

TABLE 1.—*Rainfall (in inches) at Ventura, Calif., about 8 miles from the experimental plots*

Month	1949	1950	1951	17-year average
January	1.56	2.96	2.16	2.74
February	1.39	3.07	2.34	3.45
March	1.38	0.67	0.06	3.07
April	0	.68	1.72	1.04
May	0.87	0	0	0.08
June	.18	.10	0	.08
July	0	.20	0	0
August	0	0	.01	.04
September	0	.17	0	.09
October	0	.41	.83	.65
November	1.00	1.52	1.56	.80
December	3.93	.22	5.06	3.35
Total	10.31	10.0	13.74	15.39

Since the planted rows were well within the borders of the plots, the entire crop in each row was harvested. With the exception of the tomatoes, which were spaced 5 by 5 feet, the distance between the rows was 30 inches (fig. 3).

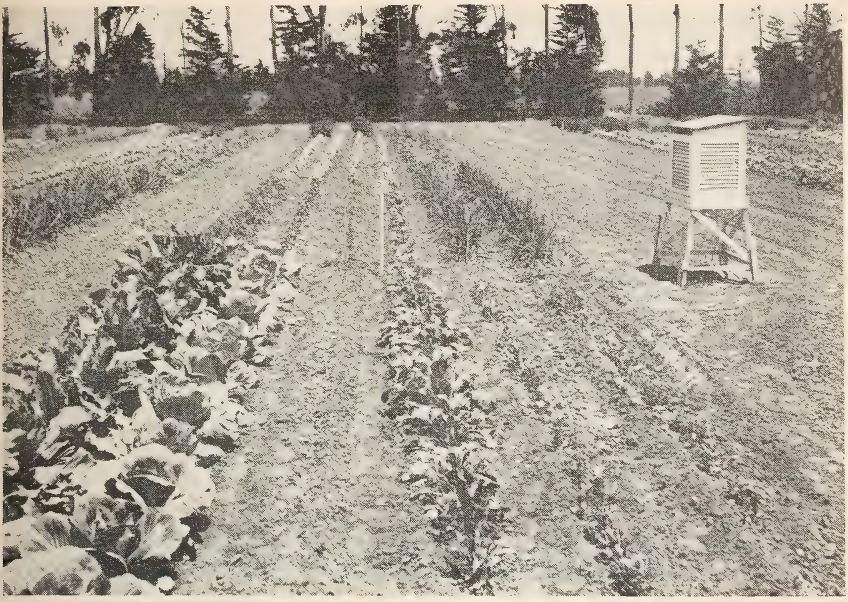

FIGURE 3.—Arrangement of vegetable plantings in a single plot.

Small seeds were sown with a single-row garden planter, larger seeds such as lima beans with a cylinder-type hand planter, which spaced the seed at the desired distance. Plants for transplanting were grown in flats in the greenhouse and then set out in the field by hand.

The plots were kept free of weeds during the winter months; after the crops had been planted they were cultivated and weeded at 2-week intervals. The crops were irrigated as uniformly as possible by regulating the flow and irrigating the furrows in each plot the same length of time (fig. 4). In 1949 the crops were irrigated on May 25 and June 29; in 1950 on March 30, May 18, and July 6; and in 1951 on April 5 and June 8.

PEST CONTROL

The fumigation with ethylene dibromide in 1949 did not prevent wireworms from damaging some of the plots in 1950, and it was necessary to fumigate the soil again on February 17, 1951, with 2 gallons of ethylene dibromide per acre.

To insure a crop it was necessary to apply an insecticide or a fungicide periodically to control other plant pests. To lessen the

FIGURE 4.—Irrigating vegetable plantings in a plot.

danger of soil contamination, minimum quantities of insecticides were used, and applications were made following cultural operations.

Tomatoes were treated from four to six times with a dust containing 5 percent of DDT and 50 percent of sulfur to control the tomato fruitworm *(Heliothis armigera* (Hbn.)) and the tomato russet mite (*Vasates destructor* (Keif.)) The same dust was used on lima beans and onions for the control of general plant feeders such as lygus bugs, the two-spotted spider mite *(Tetranychus bimaculatus* Harvey), cucumber beetles, and thrips. To control aphids and the iris whitefly on lettuce, peppers, and other crops as well as diseases on potatoes, the plants were dusted periodically with a mixture containing 1 percent of parathion, 5 percent of zineb, 5 percent of DDT, and 15 percent of sulfur. Aphids on cole crops were checked with a 10-percent nicotine dust and caterpillars with a 5-percent DDT dust.

TESTS ON DIFFERENT CROPS

The specific treatments of the different crops and their tolerance to insecticides applied to the soil in which they were grown are discussed in subsequent sections. The numbers of plants and yields in the treated plots each year are presented in tables 2–5.

LIMA BEANS

Lima beans—varieties Ventura and Fordhook 242—were planted on April 25, 1949, April 18, 1950, and May 8, 1951. The seeds were treated with Spergon and planted 6 inches apart in a single row 125 feet long in each plot. Although Fordhook beans are ordinarily harvested green, both varieties were cut between September 14 and 19, dried, and threshed about the second week in October. Threshing was expedited through the use of a special power thresher.

Ventura Lima Beans

Periodic inspection of Ventura lima bean plants showed that the application of the insecticides to the soil each year had not affected germination or depressed the growth of the emerging seedlings. In 1949 an excellent stand and exceptionally large yields were obtained in all plots. In 1950 the seed-corn maggot *(Hylemya cilicrura* (Rond.)) caused considerable damage to the seed and plants in the plots treated with ethylene dibromide and in the untreated plots, but bean production remained high. In 1951 there was no significant difference in numbers of plants or in the yields of lima beans between the treated and untreated plots, although the untreated plots tended to have the best stand and the largest yield. (Table 2.)

TABLE 2.—*Tolerance of vegetables to insecticides applied annually to the soil prior to planting, 1949–51*

[Aldrin applied at 4, chlordane and toxaphene at 20, and ethylene dibromide at 54 pounds per acre]

Crop and insecticide	Total plants			Yield		
	1949	1950	1951	1949	1950	1951
Ventura lima beans (750 feet of row):	*Number*	*Number*	*Number*	*Pounds*	*Pounds*	*Pounds*
Untreated	1,418	1,020	860	218	192	189
Aldrin	1,403	1,261	831	217	214	167
Chlordane	1,405	1,126	746	216	199	166
Toxaphene	1,323	1,105	849	204	196	165
Ethylene dibromide	1,388	934	784	214	200	172
Error [1]	--------	139	--------	--------	--------	--------
Fordhook lima beans (750 feet of row):						
Untreated	1,398	939	1,031	169	114	111
Aldrin	1,387	1,268	970	186	145	101
Chlordane	1,394	1,240	853	173	130	97
Toxaphene	1,365	1,152	937	168	125	93
Ethylene dibromide	1,390	1,147	973	173	124	120
Error	--------	176	--------	--------	--------	--------
Cabbage (180 feet of row):						
Untreated	84	73	87	172	196	302
Aldrin	84	74	85	194	188	306
Chlordane	84	77	84	159	188	292
Toxaphene	84	78	86	150	183	251
Ethylene dibromide	84	73	85	186	211	293

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[1] Error indicates least significant difference at $P = 0.05$. Where no figures are given the difference was not significant according to the *F* test.

TABLE 2.—*Tolerance of vegetables to insecticides applied annually to the soil prior to planting, 1949–51*—Continued

Crop and insecticide	Total plants			Yield		
	1949	1950	1951	1949	1950	1951
Cauliflower (180 feet of row):	*Number*	*Number*	*Number*	*Pounds*	*Pounds*	*Pounds*
Untreated	84	45	84	81	81	115
Aldrin	84	54	82	102	114	121
Chlordane	84	56	84	108	86	117
Toxaphene	84	59	84	102	102	105
Ethylene dibromide	84	62	83	110	116	107
Lettuce (186 feet of row in 1950 and 372 feet in 1951):						
Untreated	--------	191	412	--------	127	265
Aldrin	--------	196	374	--------	143	256
Chlordane	--------	217	418	--------	145	273
Toxaphene	--------	225	400	--------	141	247
Ethylene dibromide	--------	196	390	--------	143	273
Celery (180 feet of row):						
Untreated	90	94	125	150	296	190
Aldrin	90	93	124	164	294	161
Chlordane	90	94	125	166	341	164
Toxaphene	90	94	121	150	258	142
Ethylene dibromide	90	94	125	160	356	177
Carrots (186 feet of row):						
Untreated	--------	715	975	--------	201	177
Aldrin	--------	880	1,056	--------	248	205
Chlordane	--------	926	986	--------	246	182
Toxaphene	--------	856	870	--------	195	151
Ethylene dibromide	--------	868	833	--------	247	167
Error	--------	--------	--------	--------	42	--------
Onions (372 feet of row):						
Untreated	442	495	534	111	301	172
Aldrin	459	546	527	118	395	180
Chlordane	450	569	524	113	413	174
Toxaphene	397	565	523	87	386	151
Ethylene dibromide	431	523	459	97	371	129
Error	--------	--------	42	--------	49	36
Table beets (186 feet of row):						
Untreated	--------	224	237	--------	37	137
Aldrin	--------	227	181	--------	34	109
Chlordane	--------	206	216	--------	45	119
Toxaphene	--------	227	200	--------	34	99
Ethylene dibromide	--------	244	251	--------	55	134
Sweetpotatoes (186 feet of row):						
Untreated	--------	--------	--------	--------	--------	178
Aldrin	--------	--------	--------	--------	--------	169
Chlordane	--------	--------	--------	--------	--------	164
Toxaphene	--------	--------	--------	--------	--------	173
Ethylene dibromide	--------	--------	--------	--------	--------	149
Spinach (186 feet of row):						
Untreated	--------	--------	--------	--------	--------	102
Aldrin	--------	--------	--------	--------	--------	94
Chlordane	--------	--------	--------	--------	--------	91
Toxaphene	--------	--------	--------	--------	--------	85
Ethylene dibromide	--------	--------	--------	--------	--------	105

Fordhook Lima Beans

In 1949 excellent stands and yields of Fordhook beans were obtained in both treated and untreated plots. In 1950 wireworms destroyed much of the seed in three of the untreated plots, and the stands and yields were reduced accordingly. To determine wireworm abundance, a row of corn was planted in each plot on February 21, and 7 days later two soil samples, 3 feet long and 4 inches wide and deep, were taken in each of these rows and sifted. No wireworms were recovered in any of the treated plots, whereas larvae of the sugar-beet wireworm (*Limonius californicus* Mann.), 1.2 per foot of row, were found in the untreated plots.

Observations were made in 1950 on the extent of seed-corn maggot injury to the bean cotyledons. The beans in the plots treated with aldrin or chlordane were free of injury, but injury was evident in the untreated plots and in those treated with ethylene dibromide. Slight injury was also noted in the toxaphene plots. The infestations of wireworms and maggots and the treatments did not significantly affect the yields.

In 1951 the differences in yields were within the limits of experimental error, but there was a tendency for yields to be lower in the plots treated with aldrin, chlordane, and toxaphene, as was the case also with the Ventura beans in that year (table 2).

CABBAGE

Cabbage plants were grown each year in flats and then transplanted in the plots at 2-foot spacings in rows 30 feet long. Plantings of the Cannonball variety were made on April 18, 1949, and of the Danish Ballhead variety on February 21, 1950, and March 7, 1951. Harvest began about the middle of June and terminated during July. Yield data were obtained by weighing each marketable head after the four wrapper leaves had been removed.

In 1949 yields were low in all plots owing to the delayed planting. In 1950 and especially in 1951 yields were above average for this crop, except in the toxaphene plots. No significant differences were noted in the size or appearance of the cabbage in plots receiving different treatments, or between cabbage from treated and untreated plots. (Table 2.)

CAULIFLOWER

Cauliflower of the Medium Pearl variety was used in 1950 and of the Early Snowball variety in 1949 and 1951. The plants were grown in the greenhouse and transplanted in the plots at 2-foot spacings on April 18 in 1949, on February 21 in 1950, and on March 7 in 1951. There were 14 plants per plot each year. The time of harvest varied, beginning the latter part of May in 1951 and the first week in July 1949. Usually three cuttings were made over a period of 2 weeks. Yield data were obtained by weighing the individual heads. To determine whether the size of the plant had been affected, the leaves minus the roots were also weighed.

A statistical analysis of the yield data shows that none of the insecticides affected the growth or productivity of this crop during the 3-year period. Owing to low temperatures in 1950, some of the plants failed to head properly, but otherwise they appeared to be normal in all years (table 2).

Lettuce

Lettuce of the Great Lakes variety was seeded in rows 31 feet long on February 15, 1950, and in rows 62 feet long on March 9, 1951. Yield figures were obtained by cutting and weighing the heads as they matured.

In 1950 many of the heads became affected with slime or soft rot and therefore were discarded, but in 1951 only a few heads were affected. In neither year did the insecticides affect the germination or growth of this variety of lettuce. The similarity in yields of the treated and untreated plots confirmed the fact that this crop had not been adversely affected by these insecticides (table 2).

Celery

From 15 to 21 transplants of the Utah variety of celery were placed in each plot each year, at spacings of 18 to 24 inches. The plants were set out in the latter part of March and were cut about the middle of July. They did not reach the size of commercial plantings because there was no opportunity to irrigate them as frequently. Yields were determined by weighing the entire plants minus the roots.

None of the insecticides affected the growth or yield of celery in 1949. The applications in 1950 and 1951 also did not significantly affect the yield, although there was a tendency toward lower yields in the plots treated with toxaphene (table 2).

Carrots

Carrots of the Goldinhart variety were planted each year with a hand seeder in a single row 31 feet long in each plot. No effort was made in 1949 to obtain yield data because of the poor stand in all plots.

In 1950 wireworms were responsible for fewer plants and for the low yield of carrots obtained in the untreated plots. At harvesttime 3 percent of the carrots had one or more feeding punctures. Some wireworm damage was noted in one of the plots treated with ethylene dibromide, but not in the plots treated with aldrin, chlordane, or toxaphene. As shown in table 2, two applications of toxaphene in the spring and fall of 1949 significantly reduced the yield of carrots in 1950. In 1951, however, the differences in the yield of carrots were within the limits of experimental error (table 2).

ONIONS

Onions of the Brown Spanish variety were planted as sets in rows at 8–inch spacings. The dates of planting were April 18, 1949, February 16, 1950, and March 9, 1951, and the onions were harvested on July 28, 12 and 9, in the respective years. The tops were removed and all rotted or unmarketable onions discarded before weighing. The initial application of the insecticides did not affect the growth or appearance of the onions, and none of the treatments affected the yields. In 1950, however, wireworms destroyed some of the sets and reduced yields in the untreated plots and tended to reduce yields in those treated with ethylene dibromide. No wireworm damage was noted in the plots treated with aldrin, chlordane, or toxaphene, and these materials did not affect the growth or appearance of the onions.

Observations made in 1951 failed to reveal any differences in the time of emergence or rate of growth of the onions, but the yield in the ethylene dibromide plots was substantially reduced. In these plots more than the usual number of onions were discarded because of fusarium rot, which was primarily responsible for the low yield (table 2).

TABLE BEETS

Table beets of the Detroit Short Top variety were seeded in single rows 31 feet long on March 27, 1950, and beets of the Detroit Dark Red variety on March 12, 1951. In 1951 yields were obtained by weighing the beets and the tops from each row separately, but in 1950 only the beets were weighed.

There was no significant difference between treatments in the yield of table beets in either year. A tendency to low yields was noted in the plots treated with toxaphene and aldrin in both years, which was difficult to explain because there was no difference in the appearance or size of the plants between the treated and untreated plots (table 2).

SWEETPOTATOES

Sweetpotatoes of the Porto Rican variety were planted in 1951 only, in soil where sugar beets had failed to germinate. The slips were planted on May 16 in single rows 31 feet long at 2–foot spacings. They were harvested on October 10. There were no differences in the growth or size of the plants in the various plots, although the yield tended to be lowest in those treated with ethylene dibromide (table 2).

SPINACH

Viroflay spinach was seeded in single rows 31 feet long on March 19 and harvested on May 24, 1951. Yields were obtained by making one cutting of the leaves at the ground level after they had reached marketable size and weighing the total crop from each row separately. The germination, growth, and production of spinach were not affected by three applications of any of the insecticides (table 2).

TOMATOES

Tomato transplants of the Pearson variety were planted in the plots on April 21, 1949, March 21, 1950, and April 10, 1951. Each year 12, 10, and 8 plants were set out 5 feet apart in each plot. Three or four pickings of the ripened fruit were made between September 5 and October 2. The number and weight of the fruits picked were recorded.

In 1949 many of the plants became diseased and were removed to prevent others from becoming affected. No difference could be detected in the size of plants between the treated and untreated plots. Furthermore, none of the treatments significantly affected the yield or number of fruits picked.

Of the 300 tomato plants set out in 1950, 100 were removed because they were diseased. The remaining plants in both treated and untreated plots grew normally, and no differences in size or appearance were noted. With fewer plants the plots treated with ethylene dibromide had the lowest yield of tomatoes, but there was no significant difference in yield between any of the treatments.

None of the plants set out in 1951 were diseased or appeared to have been affected by the treatments. The number and weight of the fruit harvested in the various plots did not differ significantly (table 3).

PEPPERS

Pepper transplants of the California Wonder variety were planted in 30 feet of row per plot on May 19, 1949, April 14, 1950, and May 3, 1951. Owing to a scarcity, only 6 were set out per plot in 1949, and 10 each in 1950 and 1951. From 5 to 8 pickings of the marketable pods were made each season. Weighings were made of the entire lot of pods picked in each plot.

Frequent observations failed to reveal any marked differences in the size of the plants due to the insecticide applications. Furthermore, the differences in yields and in numbers of pods picked were not significant (table 3).

PEAS

Laxton Progress peas were planted on April 15, 1949, and the Wyola variety on March 8, 1951. They were seeded in single rows 60 feet long. The yield of peas was determined by picking all the pods in each row as they matured, on two or three occasions, and weighing each lot separately. On completion of the final picking, the vines in each row were cut at ground level and weighed. None of the differences in yield were significant (table 4).

TABLE 3.—*Tolerance of tomatoes and peppers to insecticides applied annually to the soil prior to planting, 1949–51*

[Aldrin applied at 4, chlordane and toxaphene at 20, and ethylene dibromide at 54 pounds per acre]

Crop and insecticide	Total plants			Fruits picked [1]			Yield		
	1949	1950	1951	1949	1950	1951	1949	1950	1951
Tomatoes (372 feet of row):	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Pounds*	*Pounds*	*Pounds*
Untreated	65	41	48	18,975	10,454	13,322	4,711	2,146	2,738
Aldrin	59	42	48	17,423	11,498	12,910	4,488	2,276	2,765
Chlordane	44	40	48	13,341	10,801	12,990	3,496	2,251	2,694
Toxaphene	58	44	48	15,928	10,479	12,762	4,110	2,295	2,631
Ethylene dibromide	59	35	48	17,758	9,836	12,878	4,553	2,007	2,713
Peppers (180 feet of row):									
Untreated	36	57	58	380	843	464	62	130	56
Aldrin	35	54	60	423	822	527	76	131	61
Chlordane	36	52	58	401	941	502	73	147	56
Toxaphene	36	52	59	379	750	593	63	111	63
Ethylene dibromide	36	53	59	362	880	620	61	131	76

[1] Differences not significant according to the *F* test.

TABLE 4.—*Tolerance of two varieties of peas to insecticides applied to the soil prior to planting, as indicated by yields on 360 feet of row*[1]

Insecticide (pounds per acre)	Laxton Progress (1949)		Wyola (1951)	
	Green pods	Vines	Green pods	Vines
	Pounds	*Pounds*	*Pounds*	*Pounds*
Untreated check	54	28	51	35
Aldrin 4	60	32	54	38
Chlordane 20	50	28	61	43
Toxaphene 20	49	28	43	30
Ethylene dibromide 54	56	30	46	36

[1] Not significant according to the *F* test.

POTATOES

Seed potatoes of the Bliss Triumph variety were planted 20 inches apart in rows on April 19, 1949, February 17, 1950, and March 8, 1951, and were harvested on August 2, June 22, and July 9 in the respective years. At harvesttime the potatoes were plowed up and handpicked, and all were weighed regardless of size (fig. 5).

In 1949 there was an exceptionally good stand of potatoes in all plots despite the delayed planting. None of the treatments affected the rate of emergence of the plants, and there was no significant

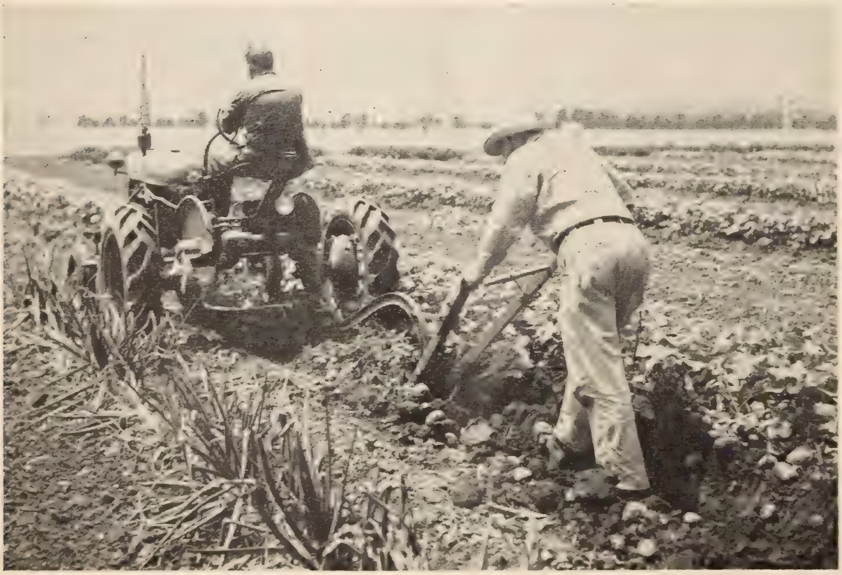

FIGURE 5.—Harvesting potatoes in experimental plots.

difference in yield between treatments. Poor yields were obtained in all plots in 1950 owing to a saprophytic growth on the leaves.[5] The yields of marketable tubers were significantly lower in the check plots owing to wireworm injury. Injured tubers were also noted in the plots treated with ethylene dibromide.

To determine the amount of damage, a 20-pound lot of potatoes from each plot was inspected and graded on the basis of the number of entrance holes per tuber. The extensive damage is difficult to explain considering the excellent control of wireworms that has been obtained throughout Ventura County with lower dosages of ethylene dibromide. It appeared that the wireworms were deep in the soil at the time of fumigation and were out of range of the vapor. The other insecticides effectively controlled the wireworms and produced potatoes of good quality.

Periodic observations of the plants in all plots throughout the 1951 season did not reveal any striking differences in the size or appearance of the potatoes. Nevertheless, there was a significant reduction in yield in the toxaphene plots after a total of 60 pounds of toxaphene per acre had been applied. There was no wireworm damage to the 1951 crop of potatoes, because the soil in the entire experimental area had been refumigated with ethylene dibromide prior to planting (table 5).

RESIDUE ANALYSES

For the study of the possibility of the absorption and translocation of the toxaphene and aldrin into the edible portions of the crop, random samples were taken from each plot and pooled to make one composite sample for each treatment. In addition, soil samples for residue analysis were taken with a soil auger 1 inch in diameter. A total of 12 borings 8 inches deep were taken at random in each replicate, or 72 per treatment. Check samples were taken in a windbreak adjacent to the treated plots. The soil samples and vegetables were submitted for analysis to the chemical firms that supplied the insecticides.

TOXAPHENE

The analyses for toxaphene residues were made by the Hercules Powder Company. Their procedure in preparing vegetables and soils for toxaphene analysis was as follows: The shelled lima beans were ground in a food chopper and extracted with benzene. The sweetpotatoes and potatoes were scrubbed, peeled, diced, dried in a forced-draft oven at 70° C., and extracted with benzene; the peels were analyzed separately from the inner portions. The soil was air-dried and extracted with a 2:1 mixture of benzene and isopropanol; the organic-chlorine content of the extract was determined in the usual way by treatment with metallic sodium fol-

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[5] J. B. Kendrick, Jr., of the University of California, diagnosed this growth as due to the organism *Stemphyllium.*

TABLE 5.—*Tolerance of potatoes to insecticides applied to the soil on 750 feet of row prior to planting, 1949–51*

Insecticide, pounds per acre	Plants			Yield			Tubers in 1950	
	1949	1950	1951	1949	1950	1951	With no wireworm injury	With at least 3 wireworm holes
	Number	*Number*	*Number*	*Pounds*	*Pounds*	*Pounds*	*Percent*	*Percent*
Untreated check	395	459	450	574	267	577	46	37
Aldrin 4	400	451	453	568	391	586	100	0
Chlordane 20	396	452	449	583	392	539	99	0
Toxaphene 20	404	457	457	512	307	475	100	0
Ethylene dibromide 54	416	448	458	631	310	548	83	6
Error				(1)	94	70		

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[1] Not significant according to the F test.

lowed by amperometric titration of the chloride ion formed with silver nitrate.

Their analyses of samples taken on August 2, 1950, of soils receiving two treatments of toxaphene, showed 7.8 p.p.m. of organic chlorine calculated as toxaphene, which was equivalent to 18 pounds of toxaphene per acre remaining in the soil to a depth of 8 inches. Similar analyses on September 1, 1951, of soils that had received three applications of toxaphene showed 16.0 p.p.m. of organic chlorine, equivalent to 37 pounds per acre of soil.

Judging by these results, about 45 percent of the toxaphene remained in the soil 10 months after the second application and 62 percent 10 months after the third application.

Their analyses for toxaphene in vegetables showed that neither the lima beans nor portions of the sweetpotatoes and potatoes grown in 1951 contained significant amounts of toxaphene, the maximum quantity being 0.3 p.p.m. found in a peel of sweetpotatoes.

ALDRIN

Analyses for insecticide residues in crops and soils from the aldrin plots were made by the Julius Hyman Company, employing the procedure described by Danish and Lidov *(2)*. Analyses of crops were made by the bioassay and colorimetric methods, and of soils by the colorimetric method.

The amount of aldrin present in dry lima beans of the 1949 crop, as determined by the bioassay method, was below the sensitivity of the method, 0.13 to 0.26 p.p.m. The amount present as determined by the colorimetric method was less than the 0.2 p.p.m. that could be measured accurately. The amount of aldrin present in the soil was found to be below the minimum detectable amount, 0.1 p.p.m., based on the 100-gram samples used.

No surface residues of aldrin were found on either the water-scrubbed or unwashed potatoes of the 1951 crop, nor were any residues detected in the peeled potatoes.

FLAVOR OF VEGETABLES

The authors and others at the Ventura laboratory tasted coded samples of the vegetables each year. In 1950 these tests indicated that aldrin and possibly chlordane were causing off-flavor to potatoes and tomatoes. Therefore, in 1951 samples of green lima beans, tomatoes, and potatoes were submitted to the Western Regional Research Laboratory of the Bureau of Agricultural and Industrial Chemistry for tests by a panel of taste experts. For this purpose random samples from the six replicate plots used for a treatment were mixed and a composite taken. The samples were taken when the crops were in the best marketable condition, neither immature nor overripe.

At the Western Regional Research Laboratory the samples of each vegetable were served on 4 days to a panel of 10 to 13 selected and trained tasters. They were told the nature of the experiment, and were asked to smell vials of the insecticides so that they might be identified if they caused much off-flavor. With the treated samples duplicate samples from the untreated plots were presented, one labeled as a control and the other coded. The judges were asked to score each coded sample with numbers ranging from 7, for no off-flavor, to 1, for much off-flavor. The lima beans were boiled 20 minutes and drained before being served. The tomatoes were sliced and served raw. The potatoes were peeled, quartered, steamed 25 minutes, mixed with one-sixth their weight of water, beaten 3 minutes in an electric mixer, and served.

A statistical analysis of the scores for lima beans and tomatoes showed no differences significant at the 5-percent level.

Since the scores for the potato samples showed differences, they were appraised a second time. An analysis of variance of the pooled data from the two appraisals gave the following results:

Aldrin	5.89
Chlordane	5.91
Toxaphene	5.75
Untreated control	6.40
Least significant difference:	
At P = 0.05	0.36
At P = 0.01	0.48

The interaction of treatments with judges was not significant at P = 0.05. Thus all samples from plants taken from treated plots were found to have more off-flavor than the controls, under the conditions of the experiment, the differences being significant at the 1–percent level of probability. No judge indicated that the flavors were similar to those of any of the insecticides.

These findings do not mean that the average consumer, or even one having an unusually acute sense of taste, would necessarily detect an off-flavor in treated potatoes as they would ordinarily be served at the table. They do show, however, that certain people after training were able to detect differences in flavor when they directly compared the treated samples with the control, under highly favorable conditions. The judges also reported that all samples, including controls, had an earthy or bitter taste. Off-flavors due to insecticides might be more conspicuous in potatoes with a blander natural flavor.

SUMMARY

Studies to determine the effect of annual soil applications of toxaphene and chlordane at 20 pounds, aldrin at 4 pounds, and ethylene dibromide at 3 gallons per acre on vegetable crops were begun at Oxnard, Calif., in March 1949. Each of these treatments and an untreated check were tested in six randomized blocks on 15 kinds of vegetables for 3 years.

The growth and yield of the following crops were not affected by any of these treatments: Tomatoes, peppers, cabbage, cauliflower, spinach, lettuce, beets, peas, sweetpotatoes, and the Ventura lima beans.

Following the second or third application of toxaphene there

was a trend toward lower yields of Fordhook lima beans, celery, and carrots. After three annual applications of this insecticide, the yield of potatoes was reduced substantially below that of the check plots. The yield of onions was also reduced following the third application of ethylene dibromide, but this was due primarily to the discarding of much of the crop because of fusarium rot.

Chemical analyses of the soil indicated that approximately 45 percent of the toxaphene remained in the soil a year after the second application. No significant amounts of toxaphene were present in lima beans, sweetpotatoes, or potatoes grown in soils treated with this insecticide. No residues of aldrin were found in either soils, potatoes, or lima beans after applications of 4 pounds of aldrin per acre.

A panel of experienced tasters in 1951 were unable to detect any off-flavor in green lima beans or in tomatoes grown in soils treated with aldrin, chlordane, and toxaphene, but they found potatoes to be significantly off-flavor.

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